A
DISCOURSE
ON THE
Attraction of Mountains,

DELIVERED AT THE
Anniverſary Meeting of the ROYAL SOCIETY,
November 30, 1775.

By Sir JOHN PRINGLE, Baronet,
PRESIDENT.

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M.DCC.LXXV.

GENTLEMEN,

THE ſatisfaction you diſcovered when a propoſal was laid before you, *for meaſuring the attraction of mountains*, and the manner in which you received the account of what had been done to fulfil that view, were ſuch indications of your applauſe, that your Council, ever attentive to your ſentiments, have adjudged the prize-medal of this year to the Reverend *Nevil Maſkelyne*, his Majeſty's Aſtronomer at Greenwich, the author and conductor of that experiment. The many and valuable communications of our worthy brother, preceding this inquiry, you have never failed to diſtinguiſh; but theſe his late labours, undertaken at your requeſt, with their ſucceſsful reſult, related in his Paper, intitled *Obſervations made on the Mountain Schehallien for finding its Attraction*, and inſerted in the ſecond part of the volume of your Tranſactions for this year, ſeemed to lay the

Society under ſuch obligations, as your Council preſumed you could not otherwiſe expreſs than by the higheſt mark of your approbation. In conſequence of this reflection, I have by their authority cauſed Mr. *Maſkelyne's* name, with the date of the preſent year, to be engraven on the medal, in order to perpetuate to him the honour you were this day to confer upon him; if, after allowing me to recall to your remembrance ſome of the more intereſting particulars of this diſquiſition and his operations, you ſhould not refuſe your ſanction to the judgment of your Council.

I ſhall not conſider the ſubject of attraction at large, nor touch upon any ſpecies of it, excepting what in latter times, by the effects, has been diſtinguiſhed by the name of *gravity* or *gravitation*; a property of bodies perceptible to the vulgar when things fall to the ground, but long acknowledged by this Society, to be a quality impreſſed by the Creator on all matter, whether of the earth or of the heavens, whether at reſt or in motion: *He commanded, and it was created.*

The diſcovery of this extenſive principle, the phyſics of aſtronomy, depended upon a juſt notion of the arrangement and motions of the ſpheres; for to underſtand their œconomy, it was neceſſary previouſly to know, which of the ſtars were quieſcent, which moved, and in what manner. Whoever therefore found out the true celeſtial ſyſtem, might be ſaid to have paved the way to the knowledge of that ſublime truth, the law by which the natural world is governed. But who were the inventors here? Were they Chaldeans or Ægyptians? Was it *Pythagoras*, or *Philolaus*, or any other Greek, either in their own country, or tranſplanted to the mathematical ſchools of Alexandria? I ſhall not enter upon that inquiry, as fruitleſs as obſcure. All that is clear and to our purpoſe is, that ſome of the ancient Greeks conjectured rightly about the ſtability of the ſun and the circular motion of the earth; but this was never a general perſuaſion, nor does it ſeem to have been mentioned any more after the age of *Ptolemy*, who in the ſecond century did not ſo much invent a new ſyſtem, as adopt that which now goes under his name, the prevailing one of his time, and nearly the ſame with that of *Ariſtotle*. This, though erroneous, was not perhaps incapable of improvements from celeſtial obſervations; but when the philoſophy of the ſchools was united with the Ptolemaic hypotheſis, and both were ſubjected to judicial aſtrology, then was aſtronomy debaſed to the level of the pretended learning of the dark ages that enſued, and increaſed their darkneſs.

But at the appointed time, when it pleaſed the ſupreme Diſpenſer of every good gift to reſtore light to a bewildered world, and more particularly to manifeſt his wiſdom in the ſimplicity as well as in the grandeur of his works, he opened the glorious ſcene with the revival of a ſound aſtronomy. *Copernicus* of Thorn (a Poliſh city in the Regal Pruſſia) endowed by nature with excellent talents, improved by a ſuperior degree of mathematics, and by travelling, became early in life diſguſted with the contradictions about the cauſes of the celeſtial phænomena. He had recourſe, as he himſelf informs us [*], to every author upon the ſubject, to ſee whether any had been more conſiſtent in explaining the irregular motions of the ſtars, than the mathematical ſchools; but received no ſatisfaction, till firſt, from *Cicero*, he found that *Nicetas* had maintained the motion of the earth; and next from *Plutarch*, that others of the ancients had been of the ſame opinion. *Cicero* had ſaid, that Nicetas *the Syracuſian (according to* Theophraſtus)

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[*] Præf. ad lib. de Revolutionibus Orbium Cœleſtium.

phraſtus) *held that the heavens, the ſun, the moon, the ſtars, in a word, the whole celeſtial bodies ſtood ſtill, and that, excepting the earth, nothing moved in the world; but that whilſt the earth with the greateſt celerity turned round its axis, the ſame phænomena were produced, as if it ſtood ſtill, and the heavens moved. And this ſome thought was alſo* Plato's *notion, but ſomewhat obſcurely expreſſed**.

Plutarch's words were, *Others ſuppoſe the earth to be at reſt; but* Philolaus *the Pythagorean, that it is carried in the ecliptic round the fire, like the ſun and the moon.* Heraclides *of Pontus, and* Ecphantus *the Pythagorean, make the earth move like a wheel about its center from Weſt to Eaſt, but not to change its place* †.

From theſe quotations, and what *Copernicus* farther ſays ‡, we find how little diſpoſed that great man was to plume himſelf with the inventions of others; nay, rather anxious not only to do juſtice to thoſe who had gone before him, but by their authority to ſcreen himſelf from the cenſure of innovation, abſurdity, and impiety, that awaited the publication of his doctrine. After all, the original genius of *Copernicus* was but little beholden for the diſcovery of thoſe ſublime truths, to either *Nicetas* or *Plato*, ſince it appears from *Cicero* that theſe two believed both the moon and the planets to be motionleſs. Nor could he be more aſſiſted by *Philolaus*, who taught that *the earth turned round* a *fire*; but this fire could not be the ſun, becauſe that ancient compares the motion of the earth about *the fire*, to the revolution of the ſun and moon about the earth. Laſtly, what little light *Copernicus* could draw from *Heraclides* and *Ecphantus*, I ſcarcely need ſay, ſince they, though admitting the diurnal motion of the earth, denied the annual.

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* Cicer. Quæſt. Academic. † Placit. Philoſ. lib. 3. cap. 3. ‡ Ibid.

But if *Copernicus* ſought to do juſtice, why did he not rather cite a clear and expreſs paſſage in the *Arenarius* of *Archimedes* for the fixed ſtate of the ſun, and for the motion of the earth in a circle round his body? *What moſt philoſophers call the world* (ſays that famous ancient) *is a ſphere, of which the center is that of the earth, and whereof the ſemi-diameter is equal to a right line joining the centers of the earth and the ſun. But* Ariſtarchus *the Samian, refuting this opinion, has advanced an hypotheſis, whereby the world ſhould be many times greater than what is here ſaid; for he ſuppoſes that the fixed ſtars and the ſun remain immoveable, and that the earth is* *carried in a circle round the ſun, placed in the middle of its courſe* *.

Thus far *Archimedes*, who ſeems not to diſapprove the ſyſtem, but who explains it no farther, as what he had quoted was ſufficient for his purpoſe. It is probable that the penetrating genius of *Ariſtarchus* had diſcovered the true arrangement of the whole celeſtial bodies, and thereby totally anticipated *Copernicus*; but that circumſtance is no where, that I know of, recorded; and otherwiſe, we ſhould acquit our illuſtrious reformer of plagiariſm with regard to *Ariſtarchus*, ſince neither the *Arenarius* of *Archimedes*, where that paſſage is found, nor indeed any other of his valuable remains, had ſeen the light before the death of *Copernicus*. This extraordinary perſon had even before the meridian of life completed his diſcoveries, and compriſed them in his book *de Revolutionibus Orbium Cœleſtium*, his only work; but which he had prudently ſuppreſſed, till he had maturely conſidered his ſubject, and had found a neceſſary and powerful patron, the pope himſelf, *Paul* III, a lover of aſtronomy, to protect him. Alluding to the admonition of the poet, he tells the Pontif, *he had*

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* Archimed. Arenar. ed. Oxon. 1676.

ſuffered that fruit of his labours to ripen, not nine years only, but four times nine [*]. Conſenting at laſt to the publication, he committed the care of the impreſſion to ſome friends in a diſtant city, from whom he received the finiſhed copy a few hours before he expired [†].

Few compoſitions have deſtroyed more riveted errors, or eſtabliſhed more important truths. Here, inſtead of an abſolute ſtate of reſt for the earth, it's triple motion is aſcertained, the diurnal about it's axis, the annual about the ſun, and that other known by the term *preceſſion of the equinoxes*; all which till then had been referred to the motion of the heavens. He likewiſe demonſtrated the double orbit of the moon, that is, her menſtrual motion about the earth, and her annual about the ſun. Nor did the wiſe *Copernicus* ſtop here; for, after laying this ſolid foundation of the celeſtical phyſics, he began the ſuperſtructure, by ſurmiſing a principle of *attraction* to be inherent in all matter. Thus, in refuting the peripatetic notion, that bodies fall to the ground, becauſe by a law of nature every thing heavy tends to the center of the univerſe (which they ſuppoſed to be in the center of the earth) he obſerved, that *the earth could not be the center of the orbits of ſeveral of the*

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[*] Præfat. ad lib. de Revolut.

[†] Gaſſend. in vita Copernic.

planets, becauſe of the apparent irregularities of their motions, and therefore could not be the center of the univerſe: hence, according to theſe philoſophers, there muſt be more centers than one; and if ſo, who could tell the true center, toward which all bodies were to gravitate? As for gravity, ſays he, *I conſider it as nothing more than a certain natural appetence* (appetentia) *that the Creator has impreſſed upon all the parts of matter, in order to their uniting and coaleſcing into a globular form, for their better preſervation; and it is credible that the ſame power is alſo inherent in the ſun and moon and planets, that thoſe bodies likewiſe may conſtantly retain that round figure in which we behold them* *. Farther, *Copernicus* looked upon the ſun as the chief governing power of the earth and all the other planets; for after placing the great luminary in the center, he cries out with rapture, *Profecto tanquam in ſolio regali ſol reſidens circumagentem gubernat aſtrorum familiam* †. Nor was this *government* underſtood to be exerciſed by any other power than that of *attraction*; as may be inferred from ſome of the laſt words of the celebrated *Tycho Brahe*, who perceiving the approach of death, called for the famous *Kepler* (then a young man, and his aſſiſtant in his obſervatory

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* De Revolut Orb. Cœleſt. lib. 1. cap. 9.

† Ibid. cap. 10.

at Prague) and after charging him with completing and publiſhing the aſtronomical tables which he was leaving unfiniſhed, thus addreſſed him: *My friend, although what I aſcribe to a voluntary, and as it were an obſequious motion of the planets round the ſun, you attribute to an* attractive *energy of that body; yet I muſt entreat you, that in the publication of my obſervations, you would explain all the celeſtial motions by my hypotheſis, rather than by that of* Copernicus, *which I know you would otherwiſe incline to follow*[*].

From this paſſage, which I have taken from the life of *Tycho Brahe*, it would ſeem, that though that other excellent aſtronomer was not inſenſible of ſome influencing power of the ſun over the planets, he would not however expreſs it by ſo ſtrong a term as *attraction*. But in what manner *Kepler* complied with the requeſt of his dying patron, it is not to our preſent purpoſe to mention, and therefore we ſhall only obſerve, that in his own works he conſtantly maintains the doctrine of attraction, and carries it even farther than ever *Copernicus* had done. Thus he calls gravity *a corporeal and mutual affection between ſimilar bodies, in order to their union*[†]. Again he remarks with *Copernicus*, againſt the peripatetics, that authors, *Copernicus* and *Kepler*, I thought proper to commemorate them on this occaſion, as none before them had expreſſed themſelves ſo fully, and with ſo much truth on that curious ſubject; and as none, from their days, to thoſe of Dr. *Hooke*, made any ſuch improvement, as would apologize for my taking up ſo much more of your time in recalling their ſentiments to your remembrance. Let it ſuffice to mention, that the firſt who in this country embraced that doctrine was Dr. *Gilbert* *; but who did not properly diſtinguiſh between attraction and magnetiſm; and that the next was lord *Bacon*, who, though not a convert to the *Copernican* ſyſtem, yet acknowledged an attractive power in matter †. In France we find *Fermat* and *Roberval*, mathematicians of great eminence, of the ſame opinion ‡; and in Italy *Borelli*, after *Galileo* ||, who was the firſt in that country who conceived that idea, but far from that preciſion and extenſion we find it in his contemporaries *Bacon* and *Kepler*.

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[*] Gaſſend. in Vit. Tych. Brah. cap. 5.
[†] Aſtron. Nov. in Introduct.

Before we paſs from *Kepler*, it will be proper to obſerve, that this great improver of aſtronomy did not, perhaps, after all, contribute ſo much to the advancement of this theory, by thoſe conjectures which I have related, as by ſome aſtronomical deductions from *Tycho Brahe's* obſervations, ſince known by the name of *Kepler's Laws.* The firſt was, that the planets move not in circular, but in elliptical orbits, of a ſmall eccentricity, whereof the center of the ſun makes one of it's *foci.* The ſecond, that the ſame planet deſcribes about the ſun equal areas in equal times. The third, that in different planets, the ſquares of the periodic times are as the cubes of their mean diſtances from the ſun.

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* De Magnete. † Nov. Organ. lib. 2. aphor. 36, 45, 48. Sylv. Sylvar. cent. 1. exp. 33. ‡ Montucla Hiſt. des Mathem. part. 4. liv. 8. || Syſt. Coſmic.

Such were the preparatives to the true philoſophy, and indeed excellent materials for the architect then unborn. But till ſir *Iſaac Newton* appeared, notwithſtanding the numerous and momentous diſcoveries that had been made in the heavens, by *Copernicus*, *Tycho Brahe*, *Galileo*, *Kepler*, and others, yet aſtronomy, as lord *Bacon* complained, ſtill remained but a mathematical ſtudy. The paſſage to which I allude is long, but, as tending to illuſtrate more than one particular relating to my ſubject, I cannot forbear treſpaſſing on your indulgence by the citation. *Although aſtronomy* (ſays *Bacon*) *has not been founded amiſs upon obſervation of the phænomena, yet the ſuperſtructure has hitherto kept low and weakly.*

In truth that ſcience preſents to the human underſtanding ſuch an object as Prometheus *did of old to* Jupiter, *when, meaning to impoſe upon that deity, he offered upon his altar, inſtead of a live victim, the hide of a large bullock, ſtuffed with ſtraw, leaves and oſier branches. In like manner aſtronomy exhibits the externals of the celeſtial bodies, as the cuticular part of heaven, fair indeed and artificially formed into a ſyſtem; but the entrails and the fountains of life are wanting, that is, the phyſical cauſes and reaſons; from which and from aſtronomical hypotheſes, a theory ſhould be drawn, not adequate only to account for all the phænomena; but for the ſubſtance, the motion, and influx of the heavens as they are in nature.... Scarcely is there one to be found who has inquired into the natural cauſes, either of the ſubſtance of celeſtial matter, or into the reaſon of the ſwiftneſs or ſlowneſs of the heavenly bodies, acting upon one another; or into the various degrees of motion of the ſame planet, or into the motion from Eaſt to Weſt, or of the contrary direction; nor into the progreſſions, ſtations, and retrogradations of thoſe bodies.... Nor into the cauſes of the apogæum and perigæum....I ſay, inquiries of this kind have ſcarcely been attempted, nor indeed any labour beſtowed upon the ſubject, excepting in the way of mathematical obſervations and demonſtrations. So that* *aſtronomy, ſuch as it now is, can only be reckoned among the mathematical arts; not without conſiderable diminution of its dignity; ſince were it to maintain its rights, it might rank itſelf as the nobleſt branch of philoſophy. For he that ſhall reject the fictitious divorces between the ſuperlunary and ſublunary bodies, and ſhall duely attend to the appetences and moſt general affections of matter (which both in the earth and in the heavens are exceedingly powerful, and indeed pervade the univerſe) will receive from what he ſees paſſing on the earth clear information concerning the nature of celeſtial bodies: and contrariwiſe, from motions which he ſhall diſcover in the heavens, will learn many particulars relating to the things below, that now lie concealed from us. Wherefore the phyſical part of aſtronomy we mark as* wanting, *and call it the* aſtronomia viva, *the animated aſtronomy, in oppoſition to the ſtuffed bullock of* Prometheus*.

The great *deſideratum* was ſupplied, and from the boſom of this Society, in the publication of the *Principia*, the immortal work of *Newton*. There the illuſtrious author evinces truths that had been only ſurmiſed before; and after eſtabliſhing by a juſt analyſis the laws of attraction, in a ſynthetical method proceeds to explain by them the motions and appearances of the heavenly bodies. Had not *Newton* lived, *Bacon* might have paſſed for a viſionary ſpeculator; but ſince the demands of that noble author upon the human intellects have been ſo fully anſwered in the productions of ſir *Iſaac Newton*, ſhall we not revere thoſe powers of his own mind, that could, in that dawn of philoſophy in which he lived, ſo well deſcry what parts were wanting, and what were the means of attaining them?

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* De Dign. & Augm. Scient. l. 3. c. 4.

Newton in a poſthumous treatiſe, *de Syſtemate Mundi*, compoſed before the publication of the *Principia*, and mentioned there, has ſaid, that *ſome of the latter philoſophers had ſought to account for the courſe of the planets in their orbits by the action of certain* vortices, *as* Kepler *and* Deſcartes; *or by ſome other principle of impulſe or attraction, as* Borelli, Hooke, *and others of our nation.* From this paſſage it would ſeem, that in thoſe times there had been more conjectures formed concerning attraction, than what were publiſhed; for excepting *Gilbert*, who vainly attempted to explain the mundane ſyſtem by magnetiſm, and lord *Bacon*, who never acceded to the *Copernican* hypotheſis *, I have found none of our na-

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* Atque harum ſuppoſitionum abſurditas, in motum terræ diurnum (*quod nobis conſtat falſiſſimum eſſe*) homines impegit. Bac. de Dign. & Augm. Scient. lib. 3. cap. 4.

tion, *Hooke* excepted, who in this way have left any thing on record worthy of your notice. He indeed, the early, the ingenious and moſt uſeful member of this Society, advanced in this reſearch far beyond all that had gone before him. But I ſhall not enlarge upon his improvements, as you have in your hands his *Cutlerian Lectures*, which contain them, and as I have already but too long dwelt on this part of my ſubject. It will ever redound to the praiſe of *Hooke*, that *Newton* has aſſociated him with himſelf in maintaining the true regulating cauſe of the courſe of the planets*. As to *Borelli*, though I have found in one of the pieces (a ſcarce one) of that learned Italian, a paſſage that certainly favours attraction; yet as it is neither ſo full, nor ſo explicit upon that point, as ſeveral others which I have cited, I muſt ſuſpect that thoſe parts which *Sir Iſaac* had in his eye have eſcaped my obſervation †.

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* M. Montucla has done great juſtice to Dr. *Hooke*, in this and other particulars, in his excellent work, *Hiſt. de Mathem. part.* 4. *liv.* 8.

† This is the paſſage alluded to: *Præterea manifeſtum eſt, quemlibet ſive primarium, ſive ſecundarium planetam aliquem inſignem mundi globum quaſi virtutis fontem circumdare, qui ita eos ſtringit, atque conglutinat, ut ab ipſo nullo pacto abſtrahi poſſint; ſed ipſum, quacunque contendentem, perpetuis continuiſque orbibus cogantur conſequi: videmus enim Saturnum, Jovem, Martem, Venerem, atque Mercurium Solem ipſum, Medicæa Sidera Jovem, Hugenianumque Sidus Saturnum circumire, non ſecus, ac circa Telluris Globum Luna ipſa revolvitur. Joa. Alph. Borelli Theor. Medic. Planetar. ex cauſis Phyſicis deductæ,* lib. 1. cap. 2. p. 5. Florent. 1666. 4°.

The great completer of the doctrine of univerſal gravitation had the ſatisfaction to find, from the reception it met with in this Society, that he had not laboured in vain; nay, perhaps no philoſophical author was ever more admired and followed in his own time, and in his own country, than *Newton* was in theſe kingdoms. With regard to others, *we are not to wonder*, as remarked by his eloquent Eulogiſt, *if philoſophers upon the firſt publication of the* Principia *took the alarm at the term* attraction, *as fearing the return of the* occult qualities; *or if, conſidering the difficulty of the ſubject, and the few words employed in explaining it, they wanted time fully to comprehend it* *. Theſe obſtacles have been removing by degrees, and the way at laſt has been ſo effectually cleared, that the name of *Newton* is not perhaps held in more eſtimation here, nor his principles more cordially embraced, than in thoſe very ſocieties of the learned, abroad, which at firſt ſhewed moſt unbelief, and at whoſe converſion therefore we ought moſt to rejoice.

The Royal Academy of Sciences, whilſt in an uncertain ſtate between the old and new ſyſtem of philoſophy, having, for one of the deciſive experiments, meaſured ſome degrees of latitude upon an arch of a meridian paſſing through Paris, and compared this menſuration with others, inferred the earth to be a ſpheroid with the longeſt diameter paſſing through its poles; but ſenſible that this operation had not been ſo unexceptionably conducted, as to ſatisfy either the followers of *Newton* or thoſe of *Huygens*, who both required a ſpheroid flattened at the poles, reſolved upon a farther and more accurate trial. With this view, in the year 1735, ſome choſen members from that illuſtrious Body were ſent to the polar circle, and others to the equator; at which places the differences of degrees being greater, the point in diſpute might be determined with leſs danger of error. How much to the honour of *Newton* and *Huygens* the reſult was, is ſufficiently known. All that is neceſſary to be mentioned here, is that in the year 1738, whilſt the academicians were ſtill in Peru, it occurred to M. *Bouguer*, one of that number, to put the *Newtonian* ſyſtem to another teſt, by inquiring into the attraction of mountains. This idea, which was originally from *Newton* himſelf, M. *Bouguer* communicated to his collegue M. *de la Condamine*, who readily aſſiſted in making the trial *. Thoſe gentlemen were perſuaded, that if the whole maſs of the earth were really poſſeſſed of ſuch a property, a high mountain, ſuch as nature had abundantly provided in that country, would ſhew ſome proportionable degree of it. That the largeſt of the *Andes* was indeed but a ſmall object in compariſon of the earth; nevertheleſs they reckoned, by a rough computation, that the attraction of *Chimboraço*, which they deemed the beſt for their purpoſe, would be equal to about the 2000th part of the attraction of the whole earth. Now, here the mountain acting as one, whilſt the earth as 2000, the direction of gravity would be viſibly turned out of the vertical line, for as much as this direction would be 1′ and 43″ towards the mountain. But how was this deflexion to be eſtimated? Only by finding the quantity of deviation of the plumb-line from a vertical poſition, by means of ſtars. In order to attain this point, they found it moſt convenient in their preſent circumſtances to take the diſtance of ſeveral ſtars from the *zenith* at two ſtations, one on the ſouth ſide of *Chimboraço*, and the other a league and a half to the weſt; that is, at ſuch a diſtance from the firſt ſtation, as that the plumb-line ſhould be but little affected by the mountain. This diſpoſition being made, they proceeded to their operations, of which we have a full and clear account by M. *Bouguer*, in his valuable treatiſe intitled *Figure de la Terre*; but of M. *de la Condamine*, we have only a ſhort abctract of the narrative he preſented to the Academy; which abſtract is contained in his curious *Journal of his Voyage to the Equator*.

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* Eloge de Newton, par M. de Fontenelle.

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* Bouguer, Figure de la Terre, ſect. 7. De la Condamine, Journal du Voyage à l'Equateur.

From both it appears, that though thoſe learned perſons, during the time employed in this experiment (which the inclemency of the air, at that height in the atmoſphere, forced them to make very ſhort) I ſay, though during this time they ſpared no pains, yet their obſervations not only varied from one another, but ſeemed to be little ſatisfactory to themſelves. M. *Bouguer* ſays, that inſtead of 1′ 43″, which the plumb-line ought to have declined from the true vertical line, the total declenſion amounted only to ſeven ſeconds and a half: an effect that fell far ſhort of the expectations of a *Newtonian*. But thoſe candid gentlemen take notice, that, *as on one hand we are ignorant of the denſity of the internal parts of the earth, which may be conſiderably greater than what appears by its ſurface*; *ſo, on the other*, Chimboraço, *which they believed likely to be as ſolid as any other parts of the ſurface of the earth, might nevertheleſs* *in many places be hollow.* Nay, M. *de la Condamine* tells us, *that he was afterwards informed of a tradition in the country, that this very mountain had once been a volcano*; and adds, that *whilſt he and his collegue were about their experiment, they had actually found ſome calcined ſtones upon it.* From which circumſtances he infers, that *if one cannot juſt draw from this trial an abſolute proof of the Newtonian attraction, one can far leſs form any concluſion againſt it.* M. *Bouguer* goes farther and obſerves, that *if we will be ſatisfied with the bare fact, it is certain from this experiment, that mountains do act at a diſtance, but that their action is much leſs than what might be expected from their bulk.* He concludes his account in the true ſpirit of a philoſopher, by ſaying, that *as in France, or in England, a hill may be found of a ſufficient height for the purpoſe, and eſpecially if the obſerver would double the action, by making a ſtation on each ſide; he ſhould be happy to hear, on his return to Europe, that the experiment had been repeated, whether the reſult tended to confirm his obſervations, or to throw ſome better light upon that inquiry.* If the Society have fulfilled the views of that worthy man, who thus called upon them, we have to regret that he did not live long enough to ſhare the ſatisfaction with us.

I come now to Mr. *Maſkelyne's* labours, upon which I ſhall not expatiate, as I have already taken up too much of your time, and as I judge it unneceſſary to dwell long upon that part of my ſubject, which you have ſo lately heard in his own words, and which you will have in a few days publiſhed at large in your Tranſactions.

I need only remind you, that the zenith diſtance of a ſtar on the meridian being obſerved at two ſtations under the ſame meridian, one on the ſouth ſide of a mountain, the other on the north; if the plumb-line of the inſtrument be attracted by the mountain out of its vertical poſition, the ſtar will appear too much to the north by the obſervation at the ſouthern ſtation, and too much to the ſouth by that at the northern ſtation; and conſequently the difference of the latitudes of the two ſtations will be found by theſe obſervations greater than it really is. And if the true difference of their latitudes be determined by meaſuring the diſtance between the two ſtations on the ground, the exceſs of the difference found by the obſervations of the ſtar above that found by this meaſurement, muſt have been produced by the attraction of the mountain, and it's half will be the effect of ſuch attraction on the plumb-line at each obſervation, ſuppoſing the mountain attracts equally on both ſides.

To perform this experiment, Mr. *Maſkelyne* made choice of the Mountain Schehallien in Perthſhire, in North Britain, of which the direction in length is nearly eaſt and weſt, it's height above the ſurrounding valley at a medium is about 2000 feet, and it's higheſt part above the level of the ſea is 3550 feet. As the greateſt attraction of the mountain was to be expected about half way up it's ſides (which happened conveniently for the purpoſe of the experiment to be pretty ſteep) two ſtations for an obſervatory were accordingly choſen, one on the north, and the other on the ſouth ſide of Schehallien. The inſtrument with which he obſerved the ſtars was an excellent ſector made by Mr. *Siſſon*; and Mr. *Maſkelyne* has related at large all the precautions he took both for adjuſting this inſtrument in the meridian at each ſtation, and for ſatisfying himſelf that the line of collimation remained unaltered. From obſervations of ten ſtars near the zenith, he found the apparent difference of the latitudes of the two ſtations to be 54″,6; and from a meaſurement by triangles, formed from two baſes on different ſides of the mountain, he found the diſtance of their parallels to be 4364 feet, which, in the latitude of *Schehallien*, viz. 56° 40′, anſwer to an arch of the meridian of 43″: this is 11″,6 leſs than that found by

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the ſector. It's half therefore 5″, 8 is the mean effect of the attraction of the mountain: and from it's magnitude, compared with the bulk of the whole earth, Mr. *Maſkelyne* diſcovered the mean denſity of the earth to be about double that of the mountain.

In the execution of this intereſting experiment, our worthy brother has not only exerted a patience and perſeverance, but a ſagacity and judgment which muſt ever redound to his honour. All doubts about an univerſal attraction muſt at laſt be terminated, and every philoſopher in that reſpect muſt now become a *Newtonian*.

If I have related but two experiments that have been made, the firſt by the *French* academicians, and the other by Mr. *Maſkelyne*, it is becauſe no more have come to our knowledge; nor do I believe that more have actually been executed. For if, in occaſional menſurations of degrees of the meridian in different parts of Europe, thoſe employed have found varieties ariſe in their meaſures that they could not otherwiſe account for, than from the attraction of the mountains among which they carried on their operations, and accordingly have referred thoſe irregularities to that very cauſe; ſuch conjectures we admit may be well founded, but the meaſurements whence they ariſe we cannot reckon among the experiments we now treat of.

But was not the doctrine of an univerſal attraction ſo fully demonſtrated by *Newton*, as not to require any farther proofs from experiments? Demonſtrated it was, but not to the conviction of every individual. True Philoſophy condeſcends to adapt her inſtructions to different capacities, and is as willing to inform by palpable experiments as by geometrical demonſtrations. But to ſay the truth, ſomething ſeemed wanting here for the ſatisfaction of even the more enlightened minds. Such we reckon thoſe were who firſt made the trial. And did not *Huygens* himſelf, one of the greateſt philoſophers and geometricians of his age, find difficulties about this principle, even after the publication of *Newton's Principia*? nor do we learn that the doubts of that great man were ever removed *. To ſay nothing of the celebrated *Leibnitz*, and his numerous followers, who to this day are either wholly unbelievers in attraction, or at beſt but ſceptics on that article.

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* Vid. Hugen. Diſſert. de Cauſ. Gravitat.

You have therefore, Gentlemen, the ſatisfaction to think that you have completed a great and acceptable work to the ſcientific world; and that, though this has been a coſtly experiment, your gracious PATRON, who ſo liberally furniſhed the means, will highly approve your expending his benefaction ſo much for the advancement of Natural Knowledge and for the benefit of the public; and will ſo much the more be diſpoſed to ſhew you the like favour on future occaſions.

But for thoſe who wanted no freſh proofs of the univerſality of attraction, they muſt ſtill partake of the advantages accruing from this experiment, as being not only the firſt that has been made, but the beſt that could be deviſed, for eſtimating the mean denſity of the earth. The operation in Peru was too imperfect for that purpoſe, and had the circumſtances of that trial been more favourable, yet the ſuſpicion of their mountain having been once a volcano, was a ſufficient reaſon for admitting no evidence from it in this part of our inquiry. But for Schehallien, as it's appearance was particularly rocky, and as ſeveral ſpecimens of thoſe rocks have been preſented to the Society, and acknowledged to be mineral ſubſtances that had never paſſed through fire, we may conſider that mountain as one of the proper patterns of the denſity of the ſurface of the earth.

Theſe, Gentlemen, are the fruits of the operations of Mr. *Maſkelyne*, during a reſidence of four months in a mean hut, on the ſide of a bleak mountain, and in a climate little favourable to celeſtial obſervations. To theſe inconveniencies, however, he ſubmitted with patience and complacency, as he went at your requeſt and in purſuit of ſcience. You have heard his chief concluſions; but permit me to add, that as this is a new mine opened in the field of nature, I am confident that theſe will not be the only productions; but that, as in all great and ſucceſsful experiments, there will be in the proſecution of this ſubject ſome valuable truths brought to light, of which at preſent we can form no particular conjecture. Mean while we have the pleaſure to find the doctrine of *univerſal gravitation* ſo firmly eſtabliſhed by this finiſhing ſtep of analyſis, that the moſt ſcrupulous now can no longer heſitate to embrace a principle that gives life to Aſtronomy, by accounting for the various motions and appearances of the Hoſts of Heaven.

MR. MASKELYNE,

THE judgment, Sir, of the Council, in awarding you the prize, having received the ſanction of the ROYAL SOCIETY, I do, in the name and by the authority of that illuſtrious Body, preſent you, their moſt worthy Brother, with this ſincere pledge of their affection; as the laſting token of their acknowledgment for your ſeveral ingenious and uſeful communications, and more particularly for this laſt painful and capital experiment, which adds no ſmall luſtre to their Tranſactions. And after expreſſing their grateful ſentiments for what you have already done for their ſervice, I would farther ſay, that they perſuade themſelves, from your talents, your love of your profeſſion, and your happy period of life, you will continue ſteddily to purſue that path which you have ſo early entered upon, and which ſo ſurely leads to great and uſeful diſcoveries. You have, Sir, in charge the nobleſt branch of Natural Philoſophy: ſuch it has ever been held by this Society, and as ſuch it ever has been cheriſhed and cultivated by them. And they flatter themſelves that their cares and ſolicitude have not been fruitleſs; ſince, from their firſt inſtitution to this day, there have never been wanting ſome excellent men in that line, to promote the ſcience, and do honour to this Community. But ſo tranſcendently great is that part of the creation, that though the Divine Author has vouchſafed, in theſe latter days, to open to the humble and patient inquirers into Nature the *Cauſes of Things*; yet we muſt ſtill cry with the ancient ſage, *Lo, theſe are part of His ways, but how little a portion is heard of them!* As much then remains to be explored in the celeſtial regions, you are encouraged, Sir, by what has been already attained, to perſevere in theſe hallowed labours, from which have been derived the greateſt improvements in the moſt uſeful arts, and the loudeſt declarations of the power, the wiſdom, and the goodneſs of the Supreme Architect in the ſpacious and beautiful fabric of the World.

FINIS.